

Review Article

Managed re-alignment: a multifaceted approach in ecological restoration of coastal floodplains

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Abstract

Low-lying coasts in Europe share a long history of land reclamation enabled by flood defences, which radically transformed natural coastal processes and buffers. Traditional coastal adaptation, by raising dykes, is increasingly challenged due to environmental and sustainability issues in light of wetland loss and the climate crisis. Managed re-alignment (MR) departs from “hold the line” coastal defence approaches by encouraging the planned removal or relocation of coastal defence lines and the incorporation of softer, nature-based flood protection. MR implies substantial changes in landscape and land use and has significant local socio-environmental implications. Despite complex conceptual, technical, ecological, political and social challenges, this approach has received increased attention in northwest Europe as a key method towards the ecological restoration of coastal floodplains. In this article, we review: (1) how MR terminology varies according to disciplinary focus, public perception and regional preferences; (2) how emerging hybrid flood defence approaches contribute to restore foreshore environments; (3) how to engage local communities in co-designing MR projects while appropriately acknowledging, valuing and compensating impacts at community level. Finally, we draw lessons learnt from past experience and highlight critical questions at scientific, political and management levels.



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Highlights:

- Managed re-alignment (MR) has been applied in Europe since the 1960s for coastal restoration.
- Restored areas nevertheless are far from compensating historical wetland losses.
- Hybrid designs foster a shift towards nature-based coastal adaptation and protection systems.
- MR supports rethinking spatial planning and advancing integrated coastal zone management.
- Local engagement is crucial for effective MR planning and better chances of successful outcomes.

Key words: Coastal adaptation, coastal wetland conservation, Europe, local acceptance, managed re-alignment inventory, nature-based solutions

Introduction

European coastal lowlands are dynamic landscapes, composed of diverse freshwater to saline habitats that have historically attracted human settlements (Kaden et al. 2023). The long tradition of land reclamation of coastal lowlands has depended on the development of flood defences and profoundly transformed coastal processes, wetland landscapes and biodiversity (especially saline, aquatic habitats, fauna and flora) and ecosystem services (including water filtration and retention, wave attenuation, carbon storage). Once considered marginal, unproductive and even dangerous, coastal wetlands have been drained and turned into agricultural land along straightened, narrow watercourses and coastlines fortified by dykes. During the 20th century, large-scale land reclamation supplied land for additional purposes, including residential, commercial and industrial, which increasingly fixed the coastline (e.g. Hoeksema (2007)). Paradoxically, this raised coastal vulnerability and created a path dependency towards hard coastal protection (e.g. Tubridy (2022)). Today, colliding multiple human interests and climate change impacts further threaten coastal socio-ecological diversity.

The recognition of the ongoing degradation of coastal wetlands has spurred restoration efforts, triggering important conservation policies (e.g. Ramsar Convention) and a change in management paradigm towards ecosystem-based approaches and nature-based solutions, which are now considered more sustainable than traditional flood risk management (Schoones et al. 2019 and see Kaden et al. 2026). In this context, managed re-alignment (MR) has progressively emerged since the 1960s in northwest Europe (Andreu-Boussut and Chadenas 2022, 2025) as a coastal management approach that has the potential to provide multiple socio-ecological benefits towards coastal resilience (Esteves 2014). Wetland restoration, based on MR, invites us to reconsider the hard defence *modus operandi* implemented in Europe for centuries and re-discover how to co-exist harmoniously with a dynamic coast and water-rich environments (Goeldner-Gianella 2008). Consequently, in sparsely populated coastal areas, MR enables the restoration of near-natural processes—via reconnection to the sea—and the reintroduction of saline conditions to artificially created freshwater or terrestrial habitats. However, the implementation of MR raises important political, social, technical and financial challenges, especially against a backdrop

of climate change, as changing conditions can create critical trade-offs between coastal protection and nature conservation (Esteves and Williams 2017; de la Vega-Leinert et al. 2018; Kiesel et al. 2020; Sánchez-Arcilla et al. 2022).

In this article, we bring together perspectives from nature conservation and coastal protection to illustrate the multiple dimensions of implementing MR to protect, restore and create wetlands. We focus on three main aspects: (1) We review how MR terminology evolved, profoundly influenced by disciplinary focus, public perception and regional preferences; (2) We consider emerging hybrid flood defence approaches that reconfigure coastal infrastructure to enable foreshore restoration; (3) We examine strategies for engaging coastal communities in the co-design of MR projects. We thereby emphasise the importance of appropriately recognising, valuing and compensating local impacts, as creating synergies between coastal defence and conservation implies striking a balance between long-term resilience and the protection of local populations. Finally, we draw lessons learnt from past experience and highlight critical questions at scientific, political and management levels.

Defining managed re-alignment

MR projects have been implemented along open coasts, within estuaries, lagoons and tidal river stretches, as well as on inland river reaches. This article focuses on coastal MR, the implementation of which has frequently aimed primarily at intertidal habitat restoration or compensation for habitat loss and, secondarily, at sustainable flood management (Esteves and Williams 2017). Although many definitions have been used in literature, none is widely accepted. Indeed, variations in implementation methods and local engagement make each MR project distinct, so that certain definitions might apply to some projects and not others, while the terms used vary across countries and have evolved through time (Box 1).

The term “managed re-alignment” was coined in the United Kingdom to avoid direct association with retreat, a term often perceived as “giving [land] away to the sea,” which carries a negative weight in the public eye and affects acceptance (French 2001). Terminology progressively changed from setback,

Box 1. Terminology variations.

Rather than providing a unifying definition of MR, we compile in the following a number of terms used more or less synonymously through time in four northwest European countries (i.e. France, Germany, the Netherlands and the United Kingdom) (Fig. 1).

We hypothesise that, beyond national preferences, the policy context in which implementation occurs plays a significant role, particularly in determining whether the primary focus is wetland restoration or flood protection. Thus, while in the United Kingdom, the primary focus of MR has been on optimising flood protection and coastal adaptation, so far in France and Germany most projects focus on wetland restoration. In contrast, in the Netherlands, MR is primarily associated with enhancing the sustainability of flood defences, with a strong emphasis on nature restoration in coastal areas and on flood risk reduction along rivers (e.g. the Dutch Room for the River programme, Room for the River (2025)). Interestingly, in the United Kingdom, projects with a pronounced environmental focus were previously criticised by the public, as they were perceived not as fostering synergies between conservation and coastal protection, but as competing for limited resources (Esteves and Thomas 2014).

Today’s awareness of the climate and biodiversity crises and of nature’s value to human well-being and the economy, is contributing to a shift in perceptions. For instance, the Medmerry MR (in West Sussex, southern England) divided local opinions in its early stages, but support increased through time as the site attracted visitors interested in bird watching, cycling and walking. Similarly, the MR at Langwarder Groden (Niedersächsisches Wattenmeer National Park, Germany), which was designed to compensate for habitat loss related to the construction of the Jadeweser Port container terminal, was poorly received during the first years of public consultation. Acceptance increased when amenity value (in the form of two hiking trails partly accessible to bicycles and people with reduced mobility) was added to the project after pressure from the local community.

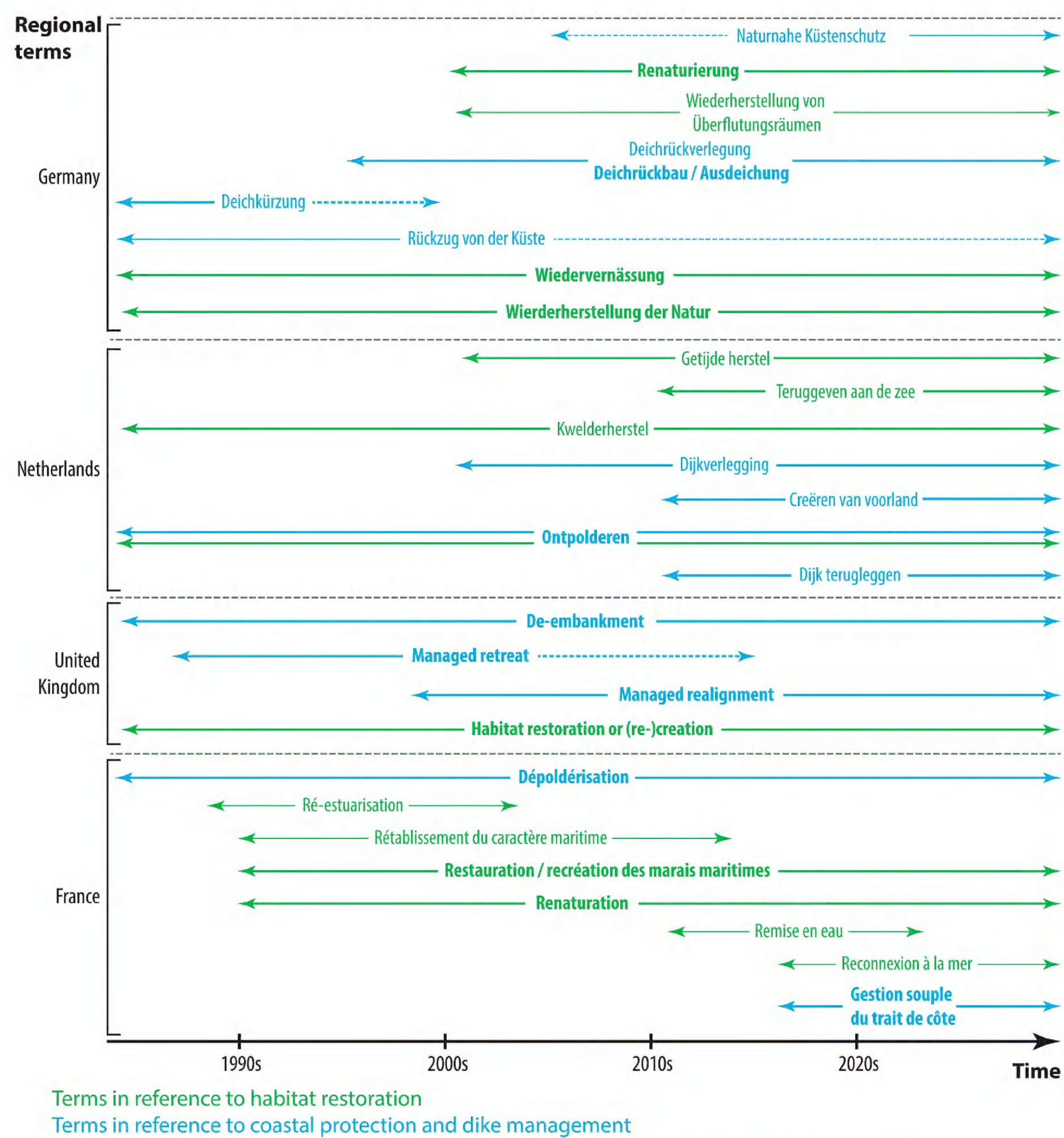


Figure 1. The evolution of MR terminology over time in Germany, Netherlands, United Kingdom and France.

to managed retreat and, eventually, to managed re-alignment (Pethick 2002). This semantic displacement in itself does not resolve controversy, although it usefully broadens the scope of this coastal adaptation approach. Indeed, ‘re-alignment’ refers to changes in the position of the shoreline or coastal defences and ‘managed’ indicates a planned action (Esteves 2014). This differentiates MR from accidental breaching of defences, also described as de-embankment, although, in some cases, planned actions can start after accidental breaches, as seen in île de la Maréchale and Baie de Lancieux (Conservatoire du Littoral 2023). In this respect, the UK Department for Environment Food and Rural Affairs (DEFRA 2002, p.1) provided a useful definition of MR that encompasses a broad range of objectives and forms applicable to many projects:

Managed re-alignment means the deliberate process of realigning river, estuary and/or coastal defences. This may take the form of retreating to higher ground, constructing a set-back line of defence, shortening the overall defence length to be maintained, reducing wall or embankment heights or widening a river flood plain. The purpose of managed re-alignment schemes might be to:

- *Reduce defence costs by shortening the overall length of defences to be maintained;*
- *Increase the efficiency and long term sustainability of flood and coastal defences by re-creating river, estuary or coastal habitats and using their flood and storm buffering capacity;*
- *Provide other environmental benefits through re-creation of natural habitats; or*
- *Provide replacement habitats in or adjacent to a European designated site to compensate for habitat loss as a result of reclamation or coastal squeeze.*

Interestingly, although retreat and setback are mentioned as forms of MR, the description above does not prescribe the landward movement of the shoreline as an intrinsic element of MR as seen in other definitions (e.g. Myatt et al. (2003); French (2006); Bax et al. (2023)). In contrast, ‘managed retreat’ is a terminology most commonly used, particularly in the United States, to describe initiatives that remove or relocate buildings, infrastructure and/or communities from floodplain or coastal areas at high risk of flooding or erosion (e.g. Hino et al. (2017); Lauer et al. (2021); O’Donnell (2022)). Planned relocation from high-risk areas is an approach mentioned in French documents since the 1990s (Chotard et al. 2021) and embedded in policies (e.g. National Strategy for Integrated Coastal Management) since the 2010s, although, *de facto*, it has rarely been implemented. Additionally, in North America, hydrological restoration (Twomey et al. 2024) or tidal marsh restoration (e.g. Van Proosdij et al. (2023)) are umbrella terms used to describe types of projects that would be branded MR in Europe. However, these terms are equally used to describe projects solely focused on habitat restoration (e.g. Virgin et al. (2020)). Consequently, the use of such diverse and varying terminology through time and across countries and regions makes the compilation of information on MR schemes a complex task (Esteves 2014).

While MR is not a term commonly used outside the UK, it is increasingly being used in academic literature in English in Europe. Thanks to its broad scope, MR has been described as a measure that can be embedded within the wider concepts of soft engineering (Badley and Allcorn 2006; Esteves 2014), building with nature (Esteves and Williams 2017), ecosystem-based adaptation approaches (Riera-Spiegelhalder et al. 2023) and, more recently, associated with nature-based solutions (Moraes et al. 2022; Bax et al. 2023), including blue-green infrastructures (McNabb et al. 2024), aligning with other critical concepts that evolved through time.

Wetland conservation and managed re-alignment: collating European experiences

From a coastal protection perspective, MR is often portrayed as an all-encompassing measure towards wetland restoration and / or creation. The underlying rationale is that, since hard flood defences have strongly impacted coastal

wetlands, their removal will revert this degradation trend. MR can, in this respect, be an appropriate measure in some contexts, since it encourages the reactivation of natural coastal dynamics and salinity necessary for the restoration of salt marshes. Nevertheless, MR on polder land can jeopardise the preservation of freshwater wetlands and forests, which rely on the maintenance of dyke and drainage infrastructure. Coastal wetland conservation, therefore, implies prioritising benefits and defining socially acceptable trade-offs. Therefore, wetland conservation projects take different forms depending on coastal configuration, the state of coastal defences, existing policies on flood protection and nature conservation, land ownership, land use and economic values to be affected and regulations on the compensation of losses.

In this section, we present an inventory at European level that captures projects implemented to date in coastal wetlands that were, at the time of writing: (1) under some form of conservation status and (2) associated with some form of coastal protection measure (primarily dykes) before implementation (Chadenas et al. 2021). Much of Europe's low-lying dyked coastlines are under various nature conservation status (Nature reserves, National Parks and, in most cases, Natura 2000 sites). Consequently, our aim was to better understand pivotal points in conservation strategies, from traditional habitat and species-based approaches to emerging strategies that emphasise the restoration of natural processes and are aligned with climate mitigation and adaptation goals (Chadenas et al. 2024).

Our starting point was the Online Marine Registry (OMReG) database, which lists coastal habitat creation and restoration schemes in Europe (ABPmer 2024). We first selected all projects involving saline to freshwater coastal wetlands, located near estuaries or on open coasts. We then cross-checked and updated this preliminary list based on existing overviews (e.g. Esteves (2014); Van den Hoven et al. (2022)) and ongoing and unpublished (grey) literature in our selected countries, primarily obtained from online sources (e.g. websites from public authorities and NGOs, Google Search engine). Our database includes projects that have been implemented or are in the process of implementation (as the completion of such projects can take several years). Our database comprises 277 wetland conservation projects to date (up to April 2024) in eight countries (Denmark, Germany, the Netherlands, Belgium, France, United Kingdom, Ireland and Spain) (Fig. 2). We compiled information on project location, local context, landscape history, type of designation (e.g. National Park, Natura 2000 site etc.), stakeholders involved, main manager, size of the site, main objectives, triggering event, start date of work, implementation methods and mode of financing. Each project is unique and tailor-made for the site under consideration and may combine several methods in a more or less complex way.

The selected wetland conservation projects were categorised, based on the main coastal protection strategy in place, subdivided into specific approaches derived from established typologies (e.g. Esteves (2014)) (Table 1):

1. "Hold the line", where the conservation of anthropogenic, freshwater wetlands in their current state depends on hard (1.1) or soft (1.2) coastal engineering;
2. "Managed re-alignment" performed via a range of approaches (2.1 to 2.7) that fully or partly re-establish coastal dynamics, in particular flooding, with the aim of fostering habitat restoration and / or creation (e.g. salt marshes and mudflats);

- 3. “Restoration of degraded wetlands” (e.g. reed beds) with re-wetting approaches that do not restore coastal dynamics (i.e. no reconnection to the sea) and,
- 4. “Do nothing”, where habitats can evolve freely (e.g. as dyke systems cease to be maintained and accidental breaches occur during storms).

The aggregated data (Table 1) indicate that the vast majority of wetland conservation projects focus on habitat restoration, with nearly 60,000 hectares of embanked wetlands restored or in the process of being reconnected to the sea



Figure 2. Coastal wetland conservation projects at European level (Andreu-Boussut and Chadenas 2025).

Table 1. Inventory of coastal wetland conservation projects at European level categorised by type of coastal protection.

Project Type	FR	DE	NL	BE	UK	DK	IE	ES	Total
1 Hold the line									
1.1 based on hard coastal defence (primarily dykes)	1	0	0	0	3	0	0	0	4
1.2 based on soft coastal protection (e.g. sand nourishment)	2	0	0	0	4	0	0	0	6
2 Managed re-alignment									
2.1 Regulated tidal exchange through sluices	8	7	4	2	33	3	0	2	59
2.2 Controlled and reduced tide, with or without dyke relocation landwards	0	0	0	22	0	0	0	0	22
2.3 Breaching of existing dyke and construction of a new dyke landwards	2	3	2	9	19	1	3	0	39
2.4 Complete removal of existing dyke and construction of a new dyke landwards	1	4	0	3	3	0	0	0	11
2.5 Breaching of existing dykes without new dyke landwards	3	13	10	2	33	1	0	1	63
2.6 Complete removal of existing dyke without new dyke landwards	7	10	1	4	3	1	0	6	32
2.7 Landwards relocation of socio-economic activities at risk as part of a restructured spatial planning	4	0	0	1	0	0	0	1	6
3 Restoration of degraded wetlands	3	3	4	19	11	5	0	3	48
4 Do nothing	12	2	3	0	11	0	2	0	30
# projects	29	41	22	57	102	11	5	9	277
Total size (ha)	11,419	10,660	15,485	8,821	4,826	3,841	62	4,629	59,743

FR: France, DE: Germany, NL: the Netherlands, BE: Belgium, UK: United Kingdom, DK: Denmark, IE: Ireland, ES: Spain. Source: Andreu-Boussut and Chadenas (2025), based on established typologies (e.g. Esteves (2014)).

on western European shorelines in eight countries. The surface area of restored coastal wetlands has increased since 2010, but is still marginal in relation to the 1.5 million hectares of intertidal environments, which have been historically embanked on these coastlines (Goeldner-Gianella 2013). The Netherlands, France and Germany display the largest total area of wetland restoration within conservation sites, while the United Kingdom shows the largest number of implemented projects overall. Ten projects of freshwater wetland conservation via the maintenance of coastal protection measures have been recorded (e.g. Farlington Marshes, UK) with a further 48 projects aimed at the restoration of degraded wetlands.

Our inventory established that artificial breaches in coastal defences (most commonly implemented in the United Kingdom, Germany and the Netherlands) and regulated tidal exchange are the two most common approaches of wetland restoration through MR. Other (more radical) strategies that leave more room for natural processes to develop freely include the removal of coastal defences (2.6), the inland relocation of socio-economic activities (2.7) in Germany, France and Spain and the “do nothing” approach (4), which has been particularly implemented in France and the United Kingdom. Nevertheless, these data should be treated with caution as such inventory remains approximate due to the paucity of information, underestimations of certain strategies (e.g. coastal wetland conservation projects supported by “hold the line” strategies are not often monitored) and the difficulty of fitting complex projects into specific categories.

Collating data at a wide regional scale and largely based on secondary sources (as in the inventory described above) may miss relevant projects that have only been documented locally. Studies at subnational scales can address this limitation by deepening the investigation of local sources. This is illustrated by the case of the State of Mecklenburg-Western Pomerania in Germany (Box 2).

Box 2. Inventories at subnational scale: Example from the State of Mecklenburg-Western Pomerania on the German Baltic Coast.

The eastern German Baltic coast is characterised by barrier and lagoon systems, negligible tidal range and compartmentalised coastal floodplains, often backed by rapidly rising ground. Coastal floodplains have been reclaimed for agriculture, with large projects taking place during German Democratic Republic times. Since reunification, the State's coastal defence mandate has focused on settlements and the responsibility for dykes protecting agricultural polders was transferred to local land owners and users. Combined with stronger climate policies, this opens windows of opportunity for the restoration of coastal wetlands.

Despite scattered information, a local-based investigation allowed a comprehensive inventory of coastal wetland conservation projects involving MR since 1990 (de la Vega-Leinert et al. 2025). The inventory also recorded decisions not to maintain or repair coastal protection infrastructure or to discontinue sand nourishment, thereby allowing “natural” reconfiguration of the coast (e.g. via storms, degradation of flood defence due to wildlife). Multiple sources were used, including existing MR inventories, grey and scientific literature on the German Baltic, planning documentation, expert elicitation, as well as media and online searches. In total, 110 relevant wetland conservation projects have been identified (as known up to April 2024), of which 36 had been implemented via MR or were under implementation at the time of writing (Fig. 3).

Geographically, these projects are located on agricultural polders on lagoonal, sheltered coasts (30). Conservation goals primarily include the restoration of degraded mires and of natural coastal processes and habitats, such as reed beds and salt meadows. Half (19 out of 36) were performed to compensate for environmental impacts of infrastructural developments, including coastal defence (3), energy (6), transport (5) and other purposes (5). Overall, 16 projects explicitly considered MR as a way to increase coastal resilience and reduce dyke maintenance costs.

By focusing on the subnational level and practice-based experience, our results demonstrate that MR has become a critical approach to support ecological restoration in coastal floodplains of the eastern German Baltic. Our study can help policy-makers and conservationists make a case for a much-needed rethinking of long-term viability of agricultural polders against a backdrop of climate change, increasing sea-levels and degrading coastal floodplain habitats.

This map represents projects that were fully implemented or underway at the time of writing (based on de la Vega-Leinert et al. (2025)).

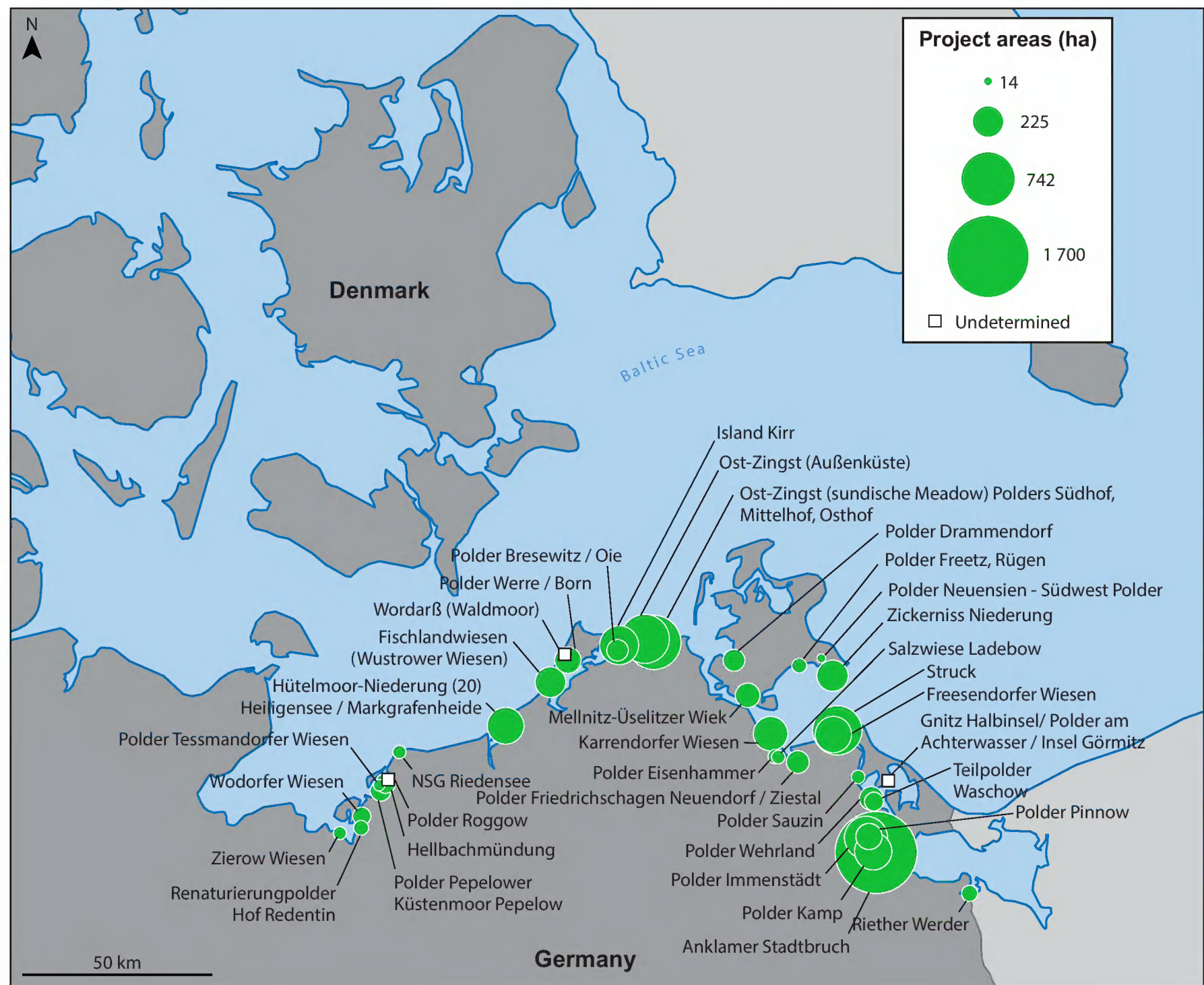


Figure 3. MR projects in the State of Mecklenburg - Western Pomerania.

There, MR has become an important strategy for coastal restoration and practitioners have accumulated substantial expertise and established best practices in its implementation. Although MR projects are well documented due to their complex planning process, tapping into this rich source of data is time-consuming, as it requires the identification, collection and analysis of dispersed grey literature in German from multiple, often difficult-to-access primary sources.

Historically, MR has often been implemented to restore coastal habitats as compensation measures (Brady and Boda 2017), thereby creating opportunities for the development of new protected areas and nature conservation projects. Nowadays, its role as an adaptation strategy to raise the resilience of wetlands to climate change is increasingly recognised (Chadenas et al. 2021). While the positive effects of MR on coastal biodiversity are now well-documented (Debue et al. 2022), a significant challenge remains in facilitating the transition of freshwater habitats into saline environments.

Combining foreshore restoration and flood protection in managed re-alignments on the North Sea

Delta areas in north-western European countries, such as the Netherlands and Germany, have a long history of reclamation of the dynamic and fertile intertidal zones characteristic of the low-lying North Sea coast. By building dykes at the outer salt marsh edge, the vegetated intertidal areas have been disconnected from the sea and transformed into agricultural land. Reclamation has, therefore, strongly impacted the ecological value of coastal areas through the impoverishment of the biodiversity of intertidal habitats (Doring 1995; Bakker et al. 2002) and the reduction of accommodation space for natural dynamics and coastal processes (Van der Meulen et al. 2007). Nevertheless, under favourable abiotic conditions, for example, in shallow intertidal zones benefitting from sheltered conditions and abundant sediment (Allen 2000), salt-tolerant plants may re-establish in front of dykes and promote sediment accumulation. Agriculture on fertile reclaimed salt marshes has often been so profitable, that several techniques have been applied to optimise abiotic and biotic conditions for the formation of yet further marshes. These techniques include: building a network of ditches to drain the intertidal zone and promote the seedling success of pioneer species; planting *Spartina* spp. to capture sediment; and erecting low brushwood dams to create a sheltered intertidal zone (Dijkema et al. 2001).

However, in a context of rising sea levels and coastal squeeze, the seaward shift of the coastline in front of dykes increasingly hinders the development of new salt marsh due to unfavourable hydraulic conditions. By reconnecting reclaimed land to the sea and restoring the accommodation space for natural dynamic coastal processes, MR can offset this trend and facilitate the re-establishment of salt marshes and their associated ecosystem services (such as natural flood protection, for example, Barbier et al. (2011)). MR can thus be designed to promote both salt marsh restoration and more sustainable flood protection (Schuerch et al. 2018). The new or enlarged foreshore adjacent to the re-aligned dyke can dissipate

wave energy through friction with vegetation and the marsh surface (e.g. Möller et al. (2014); Temmerman et al. (2023)), attenuate storm surges and high-water levels and store flood waters. The ability of MR sites to perform these functions is nevertheless determined by the properties of the restored salt marsh (i.e. elevation, width) and sediment and vegetation characteristics (Möller et al. 2014; Van Loon-Steensma et al. 2016). Nature restoration and flood and erosion protection through MR is, therefore, only sustainable if sedimentation is either in balance or exceeds erosion, so that the restored salt marsh can keep pace with sea-level rise. If this condition is not met, the restored foreshore will become progressively submerged and ultimately drown (Van Loon-Steensma and Kok 2016), resulting in important trade-offs over the long term (Van Loon-Steensma and Vellinga 2013).

MR can incorporate a hybrid flood defence (Fig. 4), which is a relatively new nature-based approach that deliberately combines grey and green elements in the flood protection infrastructure (Sutton-Grier et al. 2015; Schoonees et al. 2019) to maximise benefits for biodiversity and flood risk reduction. By carefully considering the characteristics of salt-marsh foreshores, their potential to reduce flood risk and the characteristics of the green elements in the flood infrastructure (e.g. green seaward revetment), hybrid flood defence designs may reduce dyke dimensions (i.e. slope and height) and construction requirements (Van Loon-Steensma 2015). For example, a vegetated toe dyke revetment enables a more gradual transition with the foreshore (Van den Hoven et al. 2022) and will dampen the waves (Van Loon-Steensma 2015). To date, most MR projects in Europe have been performed, based primarily on traditional grey infrastructure. The integration of hybrid flood defence in MR projects provides useful opportunities to explore innovative designs that can support salt-marsh restoration (Box 3).

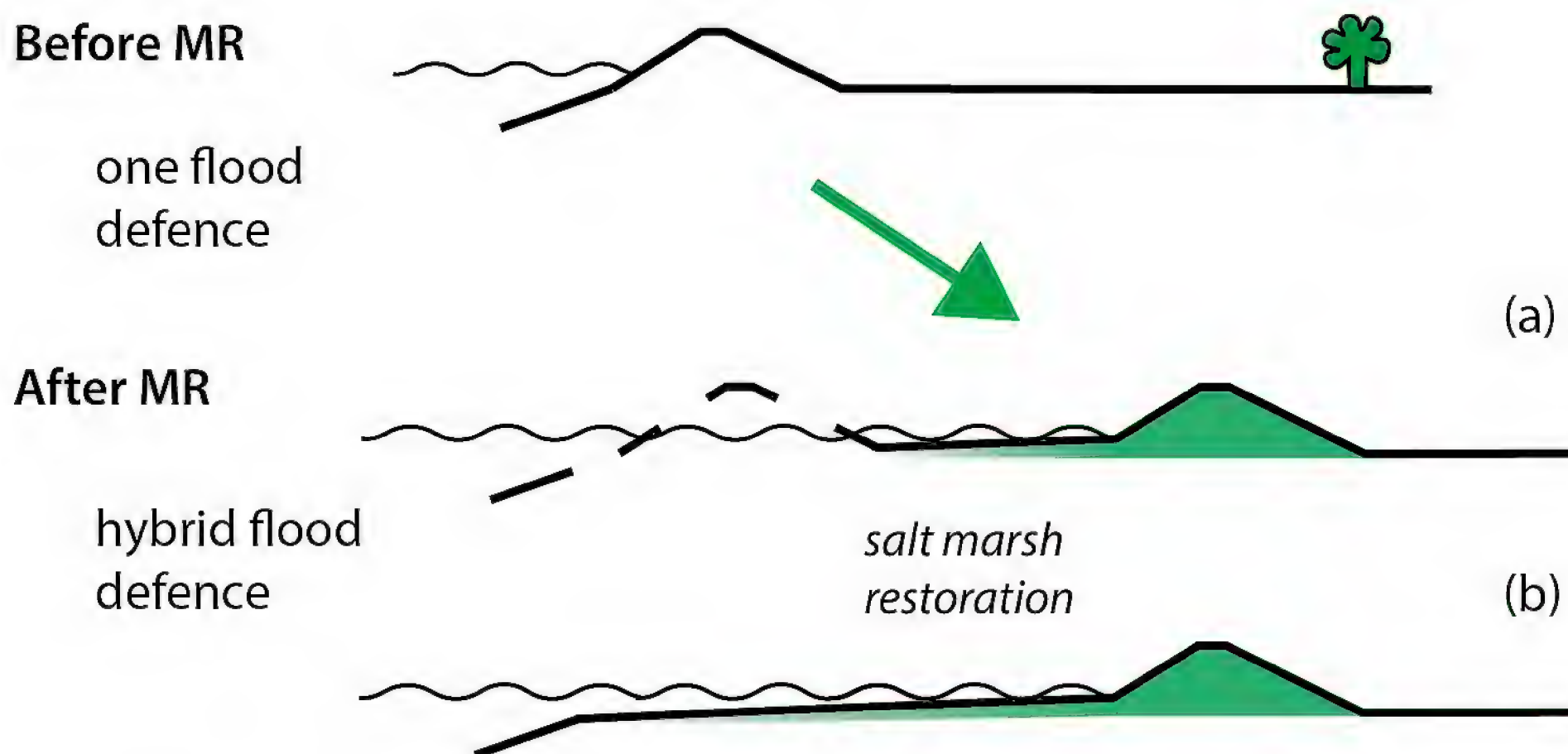


Figure 4. Cross sections of MR with a hybrid flood defence. The cross sections display seaward dykes either breached (or lowered) (a) or completely removed (b). Hybrid flood defences are represented in green. Figure after Van den Hoven et al. (2022).

Box 3. Case study: Hedwige-Prosperpolder re-alignment.

The re-alignment of the Hedwige-Prosperpolder, which lies at the border between the Netherlands and Belgium, illustrates the potential benefits of hybrid flood defence well (Fig. 2).

From the 1990s a complex decision-making process, including public consultation, resulted in the development of engineer designs for the planned re-alignment. After completion of the MR in October 2022, the re-established tidal inflow became instrumental in the restoration of the former salt marshes (Fig. 5). While the main purpose of this project is the restoration of natural intertidal areas, the development of a nature-based flood protection is an important secondary objective. The re-aligned dyke was constructed along existing secondary dykes. Its design includes a vegetated slope and a rock armour reinforcement at the toe that transitions into the foreshore (Van den Hoven et al. 2022). Although the re-aligned dyke was not explicitly planned as a hybrid coastal defence, it acts as one, so that salt marshes are in the process of recolonising the foreshore.

A specific benefit of this MR was the creation of an international Living Lab for flood protection research during the process of MR, with the original dykes serving as 'research dykes'. For example, an in-situ experiment show that it is possible to create a vegetated dyke revetment through sod transplantation from the former polders, dykes or marshes to promote the function of MR as a hybrid flood protection (Van den Hoven et al. 2024).



Figure 5. MR in action. Salt marsh slowly recolonises the former Hedwige-Prosperpolder, while the re-aligned dyke protects the hinterland from flooding (Photograph taken in May 2023 by K. van den Hoven).

Engaging local communities in coastal wetland restoration involving managed re-alignment

MR breaks a long cycle of hard engineering as the primary response to coastal flooding and erosion hazards, which most people still expect and often demand. Local communities have, therefore, become crucial to facilitate coastal wetland restoration projects. Until recently, coastal wetlands restoration has been primarily implemented, based on ecological engineering approaches and flood risk management expertise, with little to no local consultation.

Obtaining local support for such projects is, therefore, often a real challenge. General reactions to and acceptance of change are indeed influenced by personal experiences concerning how changes were communicated and by whom, the level of engagement and the perceived effects on individual or community life (e.g. Lorenzoni et al. (2007); Hobson and Niemeyer (2011)).

Communities' engagement in MR projects and its role in fostering acceptance has been investigated in Europe through detailed qualitative interviews or broader quantitative surveys on the Atlantic and North Sea coasts (Myatt et al. 2003; Ledoux et al. 2005; Goeldner-Gianella 2007; Esteves and Thomas 2014; Liski et al. 2019; Needham and Hanley 2019; Bax et al. 2023), as well as on the Baltic coast (de la Vega-Leinert et al. 2018; Schernewski et al. 2018) and the Mediterranean (Roca and Villares 2012) coasts. The literature indicates that, in recent decades, participation processes have been more routinely incorporated into MR projects, to: (i) draw on local knowledge and (ii) foster a better understanding and acceptance of ecological restoration projects.

Efforts to include local communities vary widely according to the situation at hand. At the least, they involve the communication of information on planned projects with little actual possibilities for local populations to shape projects. At best, participation processes make room for co-design and co-leadership in true collaborative projects (Rowe and Frewer 2005). Transparency in decision, planning and management processes facilitates trust-building between local communities and project managers and contributes to an "efficient implementation" (Esteves and Thomas 2014; Begg et al. 2018). Meticulous planning and early participation of local communities in project development can help to form alliances that bring a restoration project forward. On the contrary, where the local population does not feel appropriately involved in decision-making, various means of protest can be deployed, which can lead to projects being substantially delayed or even dropped (de la Vega-Leinert et al. 2018). Protests can, however, also help local residents take the lead in discussions to find acceptable solutions, for example, to accidental dyke breaches, as illustrated by the case of the Ploubalay polder in France (Box 4).

Box 4. Ploubalay polder, France.

The Ploubalay polder is located on the northern coast of Brittany (France), in the Bay of Lancieux (Fig. 6). The polder forms part of a dyke system set up by monks in the Middle Ages to extend agricultural land. Storms have frequently damaged the dyke, which has been repaired on a number of occasions.

The Conservatoire du Littoral (a public institution that acquires coastal land for natural conservation purposes) purchased the polder in 2014. A few years later, this area was investigated in the Life Adapto project with nine other pilot sites, with the aim of assessing the future evolution and adaptation potential for protected natural areas (Conservatoire du Littoral, 2023).

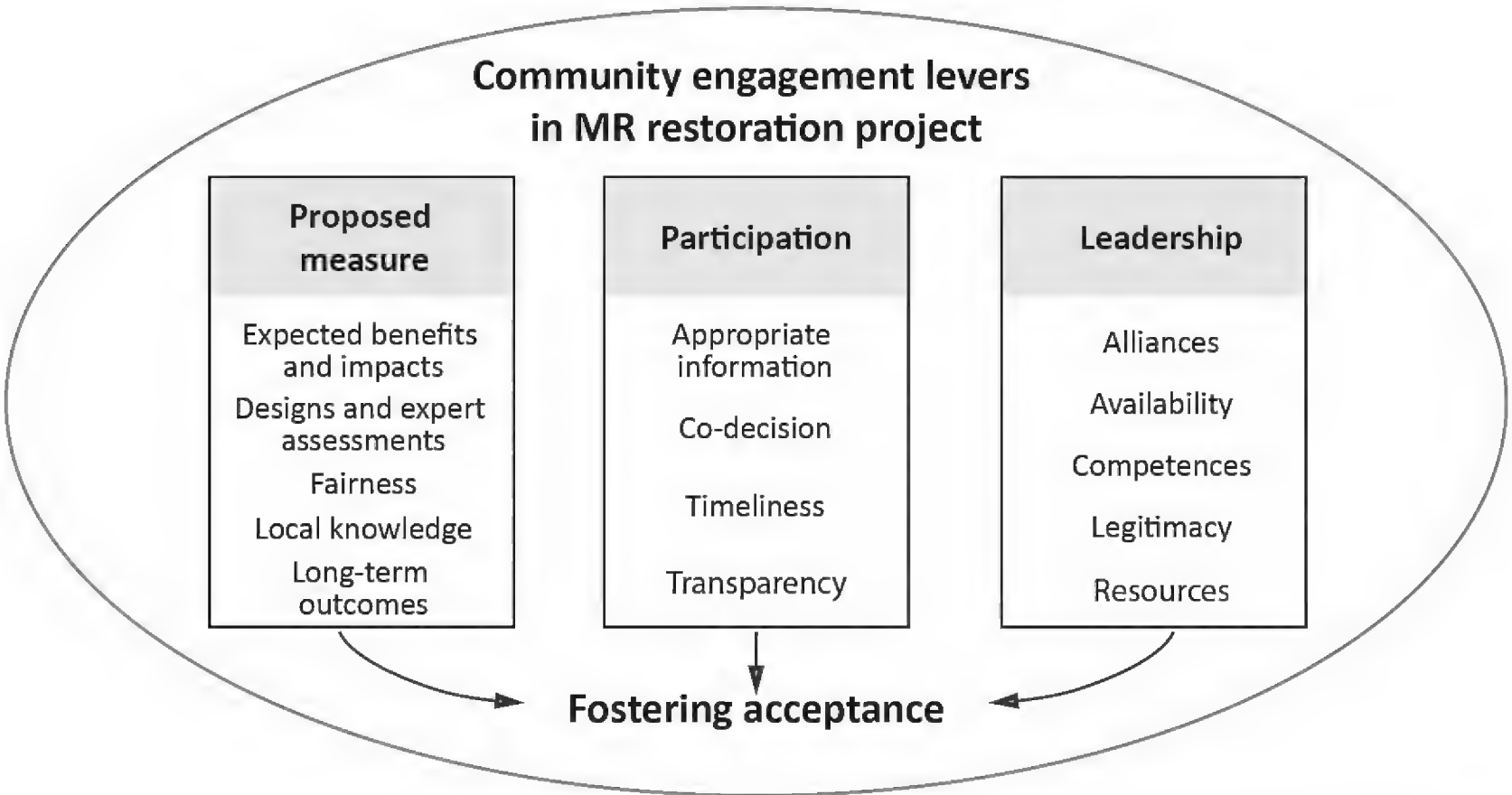
The Adapto methodological approach assesses three management scenarios set out by the French government: (i) resist (hold the line), (ii) endure (do nothing) and (iii) adapt (e.g. via MR) using the following toolboxes: hazard modelling, predictive habitat mapping, landscape forecasting and analyses of social perceptions and cost-benefits. A participative process was launched in early 2020 targeting a wide range of local stakeholders (e.g. residents, farmers, fisherfolk, hunters, tourism organisations), who engaged in several phases, including detailed interviews and workshops using the toolboxes as catalyst for discussion.

In March 2020, during the first lock-down period of the Covid-19 pandemic, a breach appeared in the dyke of Ploubalay polder. When the consultation process was able to start a few months later, participants realised that the baseline situation for the consultation process had changed. Indeed, since the Conservatoire du Littoral no longer had the means to finance the reconstruction of the dyke, the consultation process revolved around scenarios that adapted to the breached dyke (rather than scenarios that sought to reinforce the existing dyke to avoid a future breach as initially envisaged). Thus, stakeholders reflected on the future impacts of the breach on their landscape and the appropriate location of the new dyke that was to be built further inland. Thanks to the decision to accept the dyke breach, natural habitats can evolve freely in the restored intertidal areas, with salt marshes rapidly recolonising the former polder. In France, the Ploubalay polder serves as a textbook model for adaptation towards more natural coastal areas.



Figure 6. Accidental breach in the Beaussais's dyke of the Ploubalay polder in March 2020.

Several challenges must be addressed to ensure the successful engagement of local communities. First, it is important to address the concerns of local populations, as wetland restoration projects involving MR may bring uncertainties about potential impacts through increased exposure to coastal hazards (e.g. flooding), loss of land and alterations in familiar landscapes, all of which affect local place attachment (Poortinga et al. 2003). Private owners and professional users, such as farmers, are particularly exposed, as agricultural land may be lost or land use may need to be discontinued, resulting in substantial disruption of farming activities and changes in economic rentability. Compensation, whether through monetary payment or access to alternative land plots, often involves lengthy negotiations, given financial constraints, land scarcity and competition for space. Further, the loss of access to the area to be restored is often contentious (Wulf 2021). Thus, a dyke breach that closes access to a coastal footpath or decisions to stop land drainage to restore degraded coastal mires may profoundly affect recreational uses, as planning alternative routes takes time and resources (Schernewski et al. 2018). Additionally, the lack of knowledge of and interest in local species and habitats amongst communities can hinder restoration projects, as nature is often not the primary focus of local inhabitants (Chadenas et al. 2021, 2024). Finally, where restoration projects create tangible economic benefits, for example by attracting increased visitor numbers and boosting local businesses, they can obtain community support. However, increasing tourist



Quinio, adapted from de la Vega-Leinert, 2024, Nantes Université, LETG UMR 6554 CNRS

Figure 7. Leverage factors towards community acceptance of wetland restoration projects.

popularity and rising visitor numbers can dampen the enthusiasm of local residents. Consensual solutions may include new tourist infrastructure that specifically guide visitors to areas of interest, away from residents' homes.

However well prepared, there are limits to what an engagement process may achieve. Factors playing an important role in easing acceptance (Fig. 7), include: the project itself, its size, proximity to local residents' homes and farms, the credibility of the institution leading the restoration, its approachability and legitimacy, as well as available resources in personnel, finances and technology (McGrath et al. 2022). A further limitation is the prioritisation of private over public interest, which can lead to stakeholder inequalities and poor community representation; this is often exacerbated by late involvement in consultation processes, limited opportunities to influence project design or exclusion from key decisions (Begg et al. 2018; Schuerch et al. 2022).

Lessons learnt and conclusions

This article highlights the importance of terminology in framing and contextualising different approaches to wetland conservation and coastal protection. Each country has its own way of conceptualising MR and the terms chosen help create a narrative on nature conservation and coastal protection priorities, but are also influenced by societal constraints, rhythms and visions. Coastal wetland conservation has many dimensions as it encompasses the preservation of existing wetlands, the restoration of degraded mires and the creation of new habitats. While MR can restore some degree of coastal naturalness, it cannot fully align with all wetland conservation objectives. The resulting trade-offs require socially acceptable compromises and compensation for losses. Thus, MR is particularly interesting to restore: 1) (semi-)natural coastal processes; 2) connectivity between land and sea via the restoration of water exchange; 3) saline input and 4) habitats that favour these new conditions (e.g. North Sea / Atlantic Ocean: salt marshes, Baltic Sea: reed beds, salt meadows).

MR can raise coastal resilience and improve flood risk management via wave attenuation, flood water retention and allow coastal wetland to keep up with increasing sea levels, although this is conditional on: 1) the state of terrain (including degree of land subsidence associated with land reclamation); 2) sediment availability; 3) plant colonisation process and 4) rate of relative sea-level changes. If conditions are not met, restored habitats will drown over the long term. While this could be perceived as a failure from the point of view of habitat and species conservation, at social and political levels, “temporary” wetlands open a window of opportunity to think about and prepare for retreat over the medium and long term.

Synergies between wetland conservation and flood management can be achieved by combining hard and soft, grey and green coastal protection systems, such as hybrid designs that foster the restoration of salt marshes on the foreshore. A further alternative is to reconcile coastal protection with different wetland conservation goals, based on a spatial planning approach, as illustrated by the case of the East Zingst Peninsula on the East German Baltic coast (Box 5).

Where MR design must choose one goal over the other (Kiesel et al. 2020) or where it is not clear how to prioritise options, key questions to address are: how are decisions taken and how can socio-ecological gains be balanced against losses. Local community involvement is taking on a new role in navigating the complex issues raised by MR projects. Feedback on completed projects, therefore, offers invaluable insights that can provide information for future innovative and fair collaboration processes. The central benefit of MR, i.e. the promotion of coastal adaptive capacity via dynamically evolving coastal habitats and associated ecosystem services, thereby needs to be realised, recognised and widely disseminated (Fig. 9). An interesting initiative in this respect is the new action programme for natural climate protection in Germany (<https://www.natuerlicher-klimaschutz.de/>).

Box 5. Ecological restoration on East Zings, Mecklenburg – Western Pomerania.

The Peninsula is part of the Darß-Zingst barrier and lagoon system connected to Mainland via the Fischland spit. A large part of its low-lying coastal floodplains has been reclaimed during German Democratic Republic times for cattle ranching and lies today within the National Park “Nordvorpommersche Boddenlandschaft” that was designated shortly after reunification, mostly on public land.

The outer coast of the Fischland-Darß-Zingst region is of strategic importance for the coastal protection of settlements located on the inner lagoonal coast. Indeed, its complex coastal protection system and the narrow inlet located eastwards of the Peninsula strongly restrict the impacts of incoming coastal surges on the inner lagoonal coast, where dykes are comparatively low. In 2003, a complex combined coastal protection and conservation project involving the construction of a dyke across the East Zingst Peninsula, one of the core zones of the National Park, was approved as the most cost-effective coastal defence option for the region (de la Vega-Leinert et al. 2018).

To compensate for the profound environmental impacts of the new dyke, the coastal authorities in negotiations with the forest and national park administrations agreed to three spatially distinct wetland conservation measures:

- to the west (2009): re-wetting of the highly valued freshwater Osterwald forest mire was performed by raising water tables, although no reconnection to the lagoon was permitted. Instead, existing dykes were reinforced and one dyke was relocated inland.
- to the north: the dyke was breached in 2018 to restore natural coastal processes. Flooding during coastal surges has since resulted in the forest progressively dying out and being replaced by reed beds.
- to the south: the dyke is to be breached to restore salt meadows and expand resting areas for migrating birds on the Sundische Meadows.

MR combined with spatial planning, a common approach in protected area management, therefore enables attending different, often mutually exclusive, wetland conservation priorities, in this case: the reactivation of natural coastal dynamics and wetland buffers, the restoration of cultural landscapes (e.g. biodiverse meadows) and the protection of anthropogenic freshwater biomes. Where synergies cannot be achieved in a single area, zoning can help create creative compromise solutions.

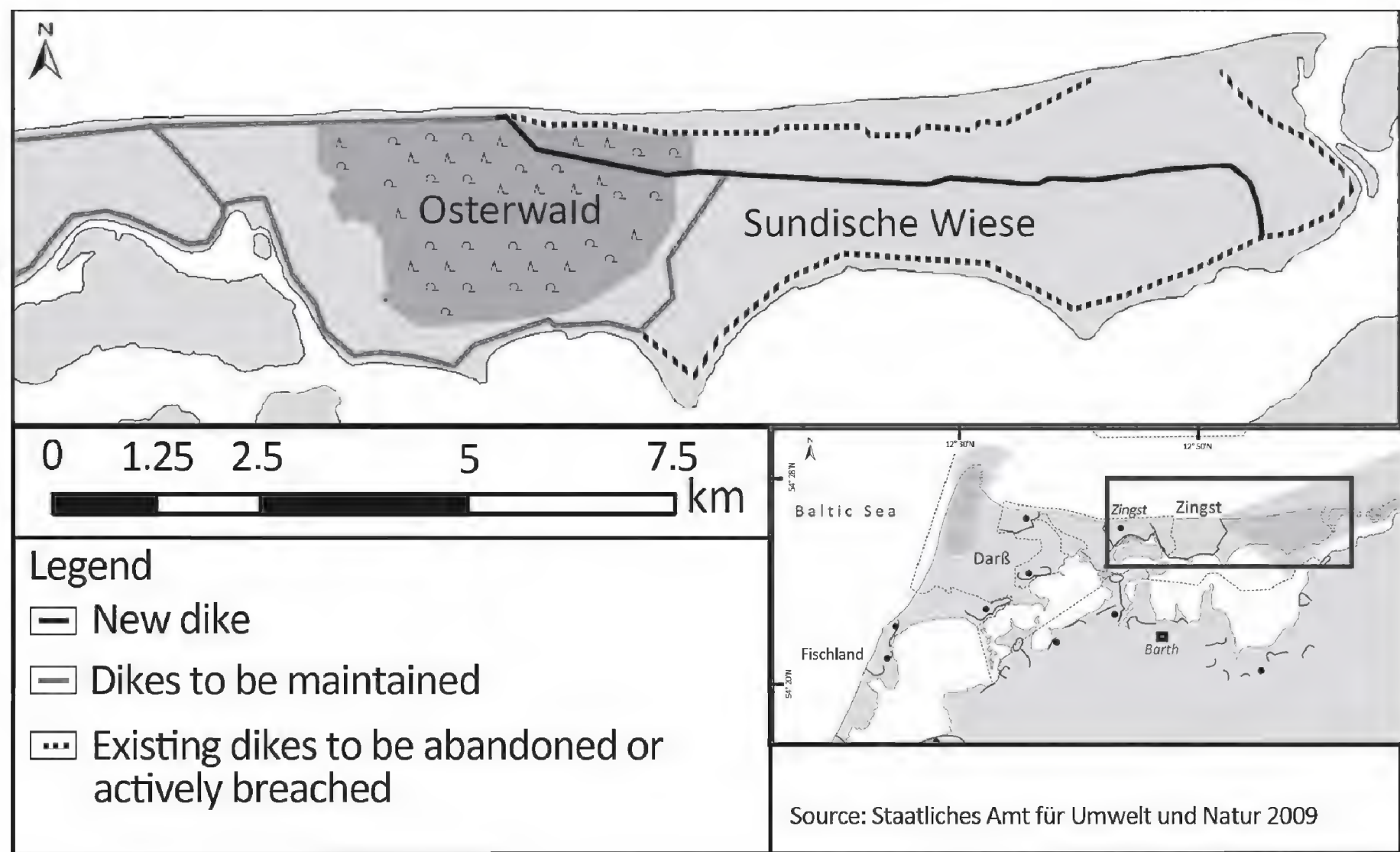
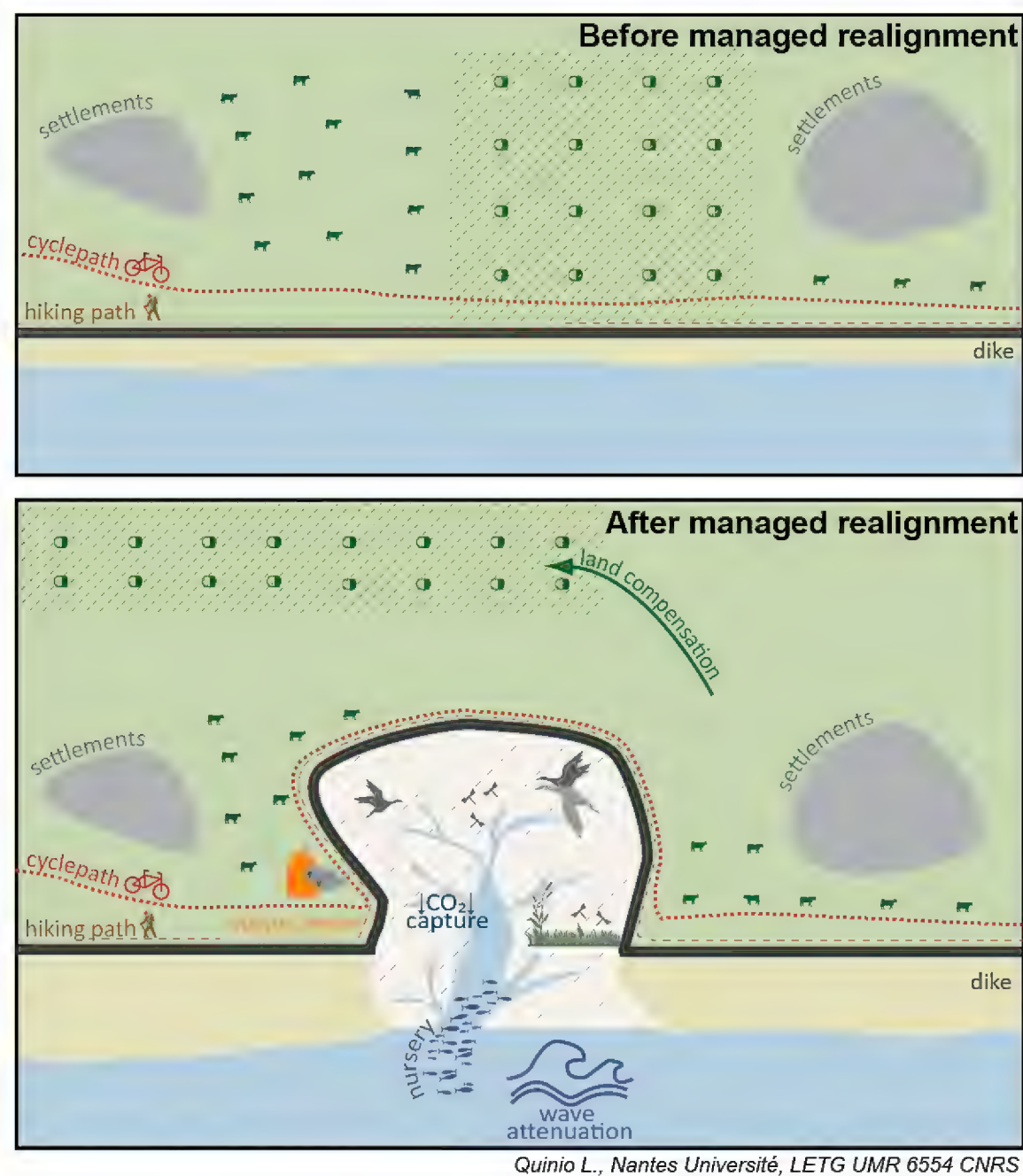


Figure 8. MR on the East Zingst Peninsula. Source: de la Vega-Leinert et al. (2018). Reproduced and modified with permission from the Coastal Education and Research Foundation, Inc.



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Figure 9. Socio-environmental changes and possible synergies for MR schemes depending on project design and local settings (Quinio after Esteves and Williams (2015) and Chadenas et al. (2021)).

With its substantial funding framework, clear targets for the restoration of wetlands, explicit endorsement of MR as one of the desirable measures to achieve these and tailored communication strategy, this programme clearly aims at creating a positive narrative on the benefits of wetland restoration and showcasing best practice examples.

Learning from both mistakes and success stories can contribute to changing mindsets and promoting the acceptance and sustainability of MR. In this regard, our article demonstrates that case studies and inventories of wetland conservation projects provide important insights:

- Western Europe has a long history of coastal nature conservation involving some form of re-configuration of the coast, with wetland restoration projects documented primarily from the coasts of the North Sea, the Channel and the eastern German Baltic Sea.
- Taken together, these projects have enabled the restoration of extensive coastal wetlands, though this remains insufficient to offset historical losses;
- MR is performed in a variety of contexts, following a range of approaches, with very different results.
- Achieving success in MR requires fulfilling various biophysical, technical, financial and management prerequisites. Nonetheless, even when these conditions are satisfied, securing local acceptance often remains the most significant challenge.
- Where local populations see their safety affected, community engagement processes can act as a lever to re-think coastal protection needs and approaches.
- Where landowners are pivotal in allowing MR, the compensation of losses, especially of land (monetary or in kind via land exchange) is critical. Further, MR project design should enable the adaptation of current land use (e.g. high value extensive pasture on salt / wet meadows, paludiculture) and the generation of alternative income (via nature-based tourism).
- Additionally, as projects take time, appropriate resources, leadership and competent teams are paramount.
- Finally, MR brings further socio-ecological benefits as it can support a more integrated spatial planning towards sustainable coastal management (see Fig. 9).

Challenges, of course, remain that should be addressed at the science, policy, management and societal levels. First, regional planning approaches, such as integrated coastal zone management, can contribute to resolving the increasing competition for coastal land, thereby freeing up areas for wetland restoration. Second, emerging conservation narratives need to be better aligned with societal views and values on coastal land use in co-designing processes. Thirdly, methodological advancements are needed to enable the comparison of MR inventories conducted with varying goals and approaches in different local contexts. Our collaborative approach, intended to bridge the gap between different scales of analysis and diverse communities of practice, is a step in this direction. Whether this will contribute to mainstreaming MR, at a time where many environmental achievements are being questioned at national, EU and world levels remains to be seen.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

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Author contributions

Anne Cristina de la Vega-Leinert: Conceptualisation, Methodology, Writing - Original draft, Writing - Review and Editing, Visualisation, Supervision. Luciana S. Esteves, Vincent Andreu-Boussut, Louise Quinio, Jantsje M. van Loon-Steensma, Kim van den Hoven: Conceptualisation, Methodology, Writing - Original draft, Writing - Review and Editing, Visualisation. Céline Chadenas: Conceptualization, Methodology, Writing - Original draft, Writing - Review and Editing, Visualization. All co-authors have reviewed and approved the final version of the manuscript.

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Data availability

The data that support the findings of this study are available in: Andreu-Boussut and Chadenas (2025) and de la Vega-Leinert et al. (2025).

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